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COMMUNITY DYNAMICS IN THE LAB: CONGESTION, PUBLIC GOOD PROVISION, AND LOCAL INSTABILITY

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Community Dynamics in the Lab: Congestion, Public Good Provision, and Local Instability

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Abstract

I study the dynamics of voluntary local public good provision in a free-mobility environment when agents differ substantially in the benefit they receive from the public good provided within their community. I find that subjects move in response to both provision and community composition but that the growth and stability of these communities are dictated by movement costs and crowding. When the public good is congestible, such that returns are lower for larger populations, communities are characterized by instability, cyclical fluctuations in local provision, and a dynamic in which low demanders continually chase high demanders through locations. When congestion is eliminated, agents with different preferences sometimes co-exist, but chronic, inefficient movement persists, suggesting that instability is driven by intrinsic preferences for community composition, as well as by sensitivity to congestion. While communities with high entry fees primarily attract those with high public good returns, segregation is not sufficient for overcoming free-riding.

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Key words: Public Goods, Group Formation, Collective Action, Experimental Economics

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1 Introduction

Achieving sufficient cooperation to allow community members to work together toward a common goal is essential for the functioning of most societies. In public goods and other collective action problems, individual incentives often diverge from the interests of the group as a whole. Since all members may consume the public good, regardless of whether they contribute to it, they have an incentive to underreport their true preferences and equilibrium behavior results in individual free-riding and a suboptimal allocation of the public good provided in the community. Efficient provision is even more difficult to achieve when residents have different preferences for public good consumption, since a community that cannot force its residents to reveal their true demand cannot require different contributions or behavior from those who would benefit most.

Charles Tiebout (1956) addressed this problem with the insight that many of the public goods and services that we consume – education, police and fire service, libraries, roads, parks, and so forth – are provided by our local communities and that non-residents may be geographically excluded from consuming them. He proposed that residents who are able to move freely between local jurisdictions would enter the community that best satisfied their preferences for the public good along with other local non-economic features (Tiebout, 1956, p.418). By moving in response to differences in local communities, residents reveal their true preferences and an efficient public good allocation can be achieved at the local level. The fundamental premise of Tiebout's argument has implications far beyond local public finance and public good provision and Tiebout's proposal is routinely invoked across disciplines to capture the idea that if we dislike our current situation we can move elsewhere – somewhere better, where the people and policies better suit our preferences, and the outcomes are more to our liking.

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This paper uses laboratory experiments to study the dynamics of local community formation, development, and stability when agents receive very different returns from the public good. I conduct simple linear public goods experiments in a free-mobility environment to gain insight into the basic underlying processes of movement, community formation, and the phenomenon of one type of agent chasing another. These experiments incorporate two fundamental features of Tiebout's framework: that public goods are spatially excludable and may be consumed only by local residents, and that residents are both fully mobile and fully informed of the differences between locations. Within this setting, I induce heterogeneous preferences for the public good and study the dynamics of movement and voluntary local public good provision. To the best of my knowledge, this paper represents the first experimental study of the importance of preference heterogeneity in movement dynamics.

These experiments also consider the importance of entry fees and congestion for community stability and address the following questions: 1) Is movement driven by agents' preferences for the public good? 2) Are instability and cyclical movement patterns caused primarily by congestion? and 3) Can entry fees facilitate sorting and local cooperation?

I find that communities experience cyclical fluctuations in local public good provision, along with perpetual movement and instability. There is a clear pattern of chasing in which those who benefit most from the public good ("High Types") enter previously unoccupied locations at an immediate cost to themselves and make high contributions to the public good. Once their community becomes competitive, they are followed in turn by those with low returns ("Low Types"), provision deteriorates, and the cycle restarts once again.

This paper also analyzes the extent to which these dynamics are driven by payoff congestion, by directly comparing experimental sessions with a congestible public good to sessions with a pure public good. A public good is congestible if it is rivalrous: the presence of more residents diminishes the benefit which each may obtain. Local entry fees are relatively higher for those who benefit very little from the public good and such fees can therefore serve as a mechanism that coordinates separation by type and may allow agents to avoid congestion. In the absence of congestion, the most efficient outcome occurs when the population pools its resources into a single community and, in this case, there is no set of residents who may increase their payoffs by collectively relocating. Though movement is less frequent in sessions without congestion, the chasing dynamic and community instability persist. This suggests that movement is partially driven by an intrinsic unwillingness to be around those who do not contribute to the community, rather than purely by payoff congestion.

Finally, I find that differences in local entry fees can facilitate the High Types' coordinated avoidance of the Low Types. Locations associated with high fees are entered almost exclusively by High Types and experience high contributions. However, even when High Types segregate, provision is not sustained and these communities are no more stable than those with low entry fees.

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Experimental studies have consistently shown that voluntary contributions in fixed-group, linear public goods games begin midway between optimal and one-shot equilibrium levels but decline with repetition, typically approaching the theoretical equilibrium unless supported by

institutions, such as sanctions or taxes for those who contribute too little (Ledyard, 1995; Ostrom, 2000).

However, in our society it is rare that we find ourselves assigned to a fixed community. We nearly always enter such groups voluntarily, with some expectations of the group outcome based on the local history or norms, and with the understanding that we can move elsewhere should we disapprove of the behavior of our neighbors. Thus a more practical approach is to study the public goods problem at the local level, where association is voluntary and movement is possible.

Despite the abundance of applications, only recently has experimental research jointly considered voluntary public goods contributions and endogenous group formation. The results thus far suggest that mobility in itself is not sufficient to solve the public goods problem without the implementation of formal boundary rules that restrict group entry and that if individuals have complete freedom to move between groups then free-riders will continuously chase contributors between societies.

Ehrhart and Keser (1999), the first to conduct such experiments, study a congestible linear public goods game. They find a group-level dynamic in which groups with high contributions grow, contributions in large groups decline, and groups with declining contributions shrink, and an individual-level correlation suggesting that higher contributors exit larger groups in favor of smaller ones. A pair of studies compared treatments in which subjects can freely move between groups, can enter only with their new group's consent, or can exit only with their former group's consent (Ahn, Isaac, and Salmon, 2008/2009). They find that subjects often vote to deny entry or approve exit, even in the pure public good treatment when groups benefit from having more members, and so, while restricted entry serves to increase contributions, earnings are lower for cooperators when the public good is pure.

Several other experimental studies have found that high contributions can be sustained in voluntary contribution public goods games when subjects are provided with a mechanism to build their groups and control membership composition (Page, Putterman, and Unel, 2005; Weber, 2006; Charness and Yang, 2010).

There is evidence that declining contributions may be explained by conditional cooperation – the willingness of subjects to cooperate only if their partners do as well – and approximately half of experimental subjects decrease their contributions if their group members contribute less (Fischbacher, Gächter, and Fehr, 2001). Faced only with the choice of how much to contribute, subjects locked into fixed groups have no other means of retaliation against free-riders and quickly learn to cease attempts at cooperation. Several experimental studies have tested conditional cooperation by sorting subjects based on the propensity for cooperation that they exhibit in earlier periods or games, and nearly all find that contribution is sustained at a higher level when cooperators only ever encounter other cooperators (Gunnthorsdottir, Houser, and McCabe, 2007; Rigdon, McCabe, and Smith, 2007; Gunnthorsdottir, Vragov, McCabe, and Seifert, 2008; Yang, Yu, and Yue, 2007; Cabrera, Fatas, Lacomba, and Neugebauer, 2009;

Burlando and Guala, 2005; Ones and Putterman, 2007; Ockenfels and Weimann, 1999; Gächter and Thöni, 2005).[1]

Experiments allowing subjects to buy entry into separate games designed to be more attractive to cooperators typically find moderate but incomplete sorting (Bohnet and Kübler, 2005; Brekke, Hauge, Lind, and Nyborg, 2008). When subjects may "vote with their feet" for local institutions and choose between groups with or without punishment mechanisms, they initially separate, with only the most cooperative joining the punishment community. However, the entire population eventually gathers in the community with punishment and achieves high levels of efficiency (Gürerk, Irlenbusch, and Rockenbach, 2006; Dorj, 2008).

Yet many important aspects of this problem remain unexplored. In addition to having different preferences for contributing or free-riding, as these studies suggest, individuals in a society typically obtain varying benefits from public good consumption. These differences are at the core of the preference revelation problem and the inability of a central government to efficiently provide public goods. While there have been several fixed-group public goods experiments considering heterogeneous preferences, there has not been any experimental work which incorporates such differences into the local public goods framework, and, to my knowledge, this is the first experimental study on the dynamics of group formation when agents have heterogeneous preferences.

This paper extends the previous experimental local public good research in several ways. First, I introduce two different types of agents: those who benefit greatly from the public good, but may be highly sensitive to congestion, and those who receive very low returns from the public good but are indifferent to the presence of others. Second, these experiments vary the cost of moving, with some locations having entry fees triple that of the others. In addition, I conduct sessions with more than twice the number of periods of the previous local public good studies to better analyze group stability and long-run dynamics. Finally, I conduct a comprehensive analysis of the importance of payoff congestion in public good returns for movement dynamics and stability, by comparing sessions in which the public good is pure (non-rivalrous) with sessions in which the public good is congestible.

2 The Setting

The experiments in this paper consider a local, linear public good that is provided by voluntary contributions from community members. There are nine agents in the population and six available locations. In each period, agents make the dual choice regarding where to locate and how much to contribute to their community once they are there. Each agent belongs to exactly one community in each period, and consumes only the public good provided within his location (there no spillovers).

All agents have the same endowment of 25 units each and differ only in their marginal per-capita return (MPCR), which is the increase in profits that the agent receives from someone in his community contributing an additional unit to the public good. Agents whose payoffs are

[1] The one exception is Ockenfels and Weimann (1999), which uses the very low MPCR of 0.33, a value at which contributions tend to be low even among cooperative subjects.

sensitive to congestion experience declining MPCR over the number of members in their community.

Let L^i_t be the location that agent *i* chooses in period *t*. In each period, each agent *i* receives a payoff that depends on his personal contribution, c^i, the total contributions made at his location, the total number of members at his location, $n(L^i_t)$, and any entry fees he may have incurred by selecting a different location than in the previous period, $f(L^i_t)$.

In each period *t*, agent *i*'s payoff is equal to:

$$\pi^i_t = 25 - c^i_t + MPCR^i(n(L^i_t)) * \sum_{j|L^j_t = L^i_t} c^j_t - f(L^i_t) * 1_{L^i_t \neq L^i_{t-1}} \qquad (1)$$

Where MPCR is equal to:

Congestible Public Good Sessions:
Low Types: MPCR = 0.15
High Types: MPCR = 1 - 0.08 (n-1)

Pure Public Good Sessions:
Low Types: MPCR = 0.15
High Types: MPCR = 0.8 if n>1
= 1 if n=1

Entry fees are the same for all agents and vary by location entered: three of the six locations have an entry fee of 5 units and the other three locations have an entry fee of 15 units. In each population of nine agents, there are five "High Types" whose MPCR is very high, such that they greatly benefit from local public good provision. In the congestible public good sessions, the MPCR of the High Types declines sharply with the number of other members in their community, thus making them very sensitive to the presence of free-riders. In the pure public good sessions, their MPCR remains high regardless of the community size. In both pure public good and congestible public good sessions, the MPCR is set at 1 when a High Type is in a community by himself, thus ensuring that between-condition differences are not driven by signaling costs. The remaining four agents in the population are "Low Types" who have an extremely low marginal per-capita return, which is constant across the number of members.

When the public good is congestible, the most efficient outcome occurs when all High Types and two Low Types locate within a single location and contribute their entire endowment of 25 units each, while avoiding the other two Low Types who locate elsewhere and contribute nothing. When the public good is pure, the most efficient outcome has all High Types and Low Types in a single location, contributing their full endowments.

Previous experimental and theoretical work can provide several baseline hypotheses in this environment. One assumption of the dynamic group formation literature is that agents myopically best respond to the previous partition (for instance, Arnold and Wooders, 2002). This assumption implies that agents move if and only if there is another location where, in the previous period, they would have done better than in their own and this magnitude is greater than that location's entry fee. But since myopic best responders should also never contribute, the public good will not be provided in any location, and so no one will ever move. This assumption provides us with the baseline prediction that neither movement nor contribution will occur.

However, voluntary contributions experiments tell us that subjects do often contribute but that very low MPCRs tend to suppress contributions. The first hypothesis is that the High Types will make higher contributions.

Hypothesis 1: High Types contribute more than Low Types.

For High Types in the congestible public good sessions, for whom MPCR declines over the number of members, this hypothesis is also extended to community size: subjects who experience payoff congestion should be less willing to contribute in large communities. However, communities may also experience *behavioral* congestion: collective action problems would cause both types of agents, in both conditions, to contribute less in larger communities. Alternatively, if types are more likely to be with other subjects of the same type, conditional cooperation implies that High Types may contribute less in larger communities in both treatments, while Low Types contribute more in larger communities.

Hypothesis 2: Contributions depend on community size: a) Payoff Congestion: High Types' contributions decline over community size in congestion sessions; b) Behavioral Congestion: Both types' contributions decline over community size in both pure and congestion sessions.

With the stipulation that some contributions will be made, the assumption that agents myopically best respond to the previous partition in their movement decisions provides the hypothesis that agents are responsive to differences in local provision levels and abandon vastly inferior communities. Specifically, agent i will move from community h to community g in period t if and only if:

$$\sum_{j|L^j_{t-1}=g} c^j_{t-1} - \frac{MPCR^i(n(g))}{MPCR^i(n(h)+1)} * \sum_{j|L^j_{t-1}=h} c^j_{t-1} > \frac{f(g)}{MPCR^i(n(h)+1)} - c^i_t \qquad (2)$$

which, when MPCR is constant over community size, reduces to:

$$\sum_{j|L^j_{t-1}=g} c^j_{t-1} - \sum_{j|L^j_{t-1}=h} c^j_{t-1} > \frac{f(g)}{MPCR^i} - c^i_t \qquad (3)$$

The third hypothesis is that relatively poorly performing communities cannot persist.

Hypothesis 3: There will exist multiple, stable, populated communities only if they are sufficiently similar.

Since High Types receive greater returns from the public good, the entry fees are relatively lower for them, and they should therefore be more responsive to slight differences in local provision and more prone to movement. The early flight of those most sensitive to deterioration in quality is a familiar phenomenon – going back to Albert O. Hirschman (1970)'s treatise on Exit, Voice, and Loyalty – and has been documented in a range of experiments in which the option to exit is available (Miller and Holmes, 1975; Yamagishi, 1988; Fujiyama et al, 2005; Ehrhart and Keser, 1999). Thus the fourth hypothesis is that High Types will be more responsive to differences in public good provision.

Hypothesis 4: High Types have a lower threshold for movement, such that they move with greater frequency and their exit from underperforming communities precedes the exit of Low Types.

Unless High Type contribution is very high, the difference in relative magnitude of entry fees may promote separation of types and support (conditional) cooperation. Since the Low Types receive little benefit from the public good, they should be willing to pay the cost of locating near the High Types only if they expect contributions to be far greater in that location than in their own. A partition of agents is Nash stable if there is no agent who would increase his payoff by unilaterally relocating. A partition of agents is strong Nash stable if there is no set of agents that could increase their payoffs by collectively relocating. When the entry fees are high enough relative to the High Type provision levels, the Low Types will be segregated from the High Types in a strong Nash stable partition. Specifically, by equation (3), if the High Types are segregated from the Low Types in a community with a low (high) entry fee, this partition will be stable if the High Types collectively contribute no more than 33 (100) units more than the Low Types. On the other hand, if the High Type contributions are very high, Low Types will wish to enter the community with the High Types and a community containing the entire population will be Nash stable. When the public good is congestible, no strong Nash stable partition exists, as the High Types would always prefer to collectively exit provided they are contributing more per person than the Low Types.

Hypothesis 5: When the public good is congestible, the relative differences in entry fees may promote sorting and separation by type.

If, on the other hand, movement is prevalent when the public good is congestible, then the dynamics when the local public good is pure are critical to understanding what is driving this pattern. When the High Types do not experience payoff congestion, a single populated community is both efficient and strong Nash stable. The direct comparison of the congestible and pure public good treatments provides insight into the motivations of those who move into a previously empty location at an immediate cost to themselves, and may lead to more general inferences regarding the role of mobility in public goods and other social dilemma games. Table 1 summarizes these motivations and implications.

Movement and Chasing in Congestion Sessions Driven By	*Predicted Dynamic in Pure Sessions*	*Implications*
Benefit to some of forming smaller communities	Single community with standard decline	Little difference from fixed group experiments
Feature of payoff function which punished agents for contributing in large communities	Single community with sustained contributions	Existence of other locations serve as a threat which sustains higher contributions
Attempt to restart cycle	Single community during most periods with movement and contribution reset	Movement is effective in restarting the public goods game
Resentment	Chasing similar to congestible public good	Cycling result is robust

Table 1: Separating motivations for the chasing dynamic

3 Experimental Design

Experiments were conducted using the experimental software z-Tree (Fischbacher, 2007) in the Laboratory for Experimental Economics and Political Science at the California Institute of Technology and in the Harvard Decision Science Laboratory at the Harvard Kennedy School of Government. Nine subjects participated in each session, and were paid based on their performance in the game. There were thirteen sessions in total: six in which the public good was pure (non-rivalrous) and seven in which the public good was congestible.

In the initial period of each session, the subjects were randomly assigned to three communities of three members each and chose how to allocate their endowment between private and public consumption. In subsequent periods, there were three additional locations, for a total of six available locations, and the participants made their decisions in two stages.

First, the subjects chose whether to stay in their current location or to move to a different location for a fee. While making this choice, they were able to observe the total contributions and number of community members in all locations, as well as their own contributions and returns, in each of the previous three periods. Movement into one of the three original locations incurred a low fee (5 units: equivalent to 20% of their per-period endowment) while movement into one of the other three locations incurred a much higher fee (15 units: 60% of their endowment). Entry fees were subtracted from their payoffs at the end of the period and thus did not restrict contributions.

Once they made their location decisions, the subjects then observed how many others were in their chosen location and made a contribution to that community's public good. Subjects were able to observe only the number of people and the total contributions in the locations, and did not receive any information regarding the location of specific subjects or individual contribution levels.

4 Results and Discussion

The following results are reported for seven sessions with congestion (one which lasted 30 periods, one which lasted 27 periods, and four which lasted 65 periods) and six sessions without congestion (one which lasted 65 periods and five which lasted 80 periods). The results are displayed for both types of sessions.

4.1. Efficiency and Overall Dynamics: Congestible vs. Pure Public Goods

Congestible Public Good

Result 1.1: Locations experience cyclical patterns of boom and bust in local provision levels.

Local public good provision in the congestible public good sessions (CPG) is characterized by cyclical patterns of boom and bust. Provision peaks shortly after community formation and declines steadily over time. Figure 1 shows the average provision level over the

life of a community. The total contributions made within a community declines over the time that it is continuously populated by at least two members.

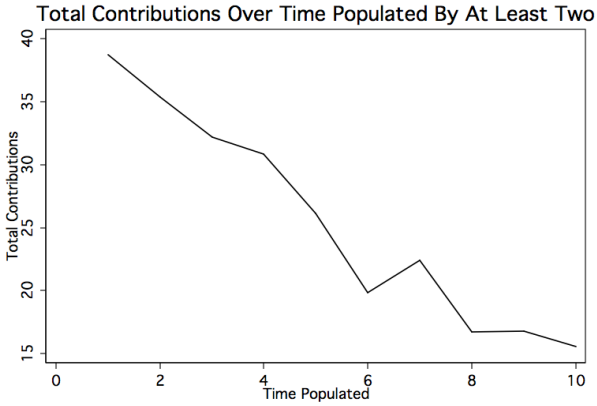

Figure 1: The total contributions made in a community over the number of periods that it has been continuously populated by at least two members

Result 1.2: When the public good is congestible, Low Types chase the High Types.

Movement is frequent – occurring in over three quarters of all periods – and communities are highly unstable. There is a clear dynamic in which Low Types continually chase the High Types, a pattern that never slows or ceases over the 65-period experiment. High Types enter previously empty locations at an immediate cost to themselves and contribute once they are there. They are then joined by fellow High Types and provision increases. The Low Types follow as soon as this new community surpasses their own. Provision levels then decline and the High Types exit once again. Table 2 presents OLS regressions of the number of High Types and Low Types in a community on the previous community composition and contribution levels. A more detailed analysis of the differences in moving patterns for the two types follows in the next section.

Dependent Variable:	# $Highs_t$		# $Lows_t$	
	(1)	(2)	(1)	(2)
	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)	Coefficient (p-value)
# $Highs_{t-1}$	.67* (<0.001)	.67* (<0.001)	.01 (0.34)	-.011 (0.37)
# $Lows_{t-1}$	-.11* (<0.001)	-.09* (<0.001)	.7797* (<0.001)	.82* (<0.001)
Total $Contributions_{t-1}$	.021* (<0.001)	.02* (<0.001)	.012* (<0.001)	.010* (<0.001)
# $Highs_{t-1}$ - # $Highs_{t-2}$	–	.06* (0.006)	–	.163* (<0.001)
Intercept	.11* (<0.001)	.11* (<0.001)	-.00008 (0.995)	.01 (0.32)
R^2	0.78	0.78	0.82	0.83
Observations	2250	2250	2250	2250

Table 2: Community composition dynamics: regressions of the numbers of High and Low Types in a location on the previous characteristics of the location

Pure Public Good

When the High Types are not sensitive to congestion, instability and perpetual movement are reduced, but not eliminated. This suggests that resentment, or unwillingness to be around free-riders, is a robust phenomenon, and not purely a feature of payoff congestion.

Result 1.3: Approximately 42% of the movement is driven by congestion.

Though all subjects are weakly better off being in larger communities when the public good is pure, subjects do exit large communities in favor of smaller ones. Subjects move in 18.35% of opportunities in CPG sessions and in 10.8% of opportunities in pure public good (PPG) sessions. However, there is considerable variation in the population dynamics between sessions when the public good is pure: in two sessions subjects move more than 18% of the time (equivalent to the congestion sessions) while in other sessions they move as infrequently as 1% of all opportunities.

Result 1.4: In some PPG sessions, subjects co-exist in a single group for most periods, while in the others, the dynamics strongly resemble those in the CPG sessions.

Figure 2 shows the distribution of the number of populated locations per period. While there are typically three communities in existence when the public good is congestible, subjects are most frequently in a single community when the public good is pure. However, this varies starkly across sessions. In the three sessions with the least movement, all subjects are together in 72.3%, 73.8%, and 93.8% of periods respectively, while in the other three sessions subjects are together only 10%, 26.3%, and 36.3% of periods. In these latter sessions, population and contribution dynamics appear very similar to those in the congestible public good sessions.

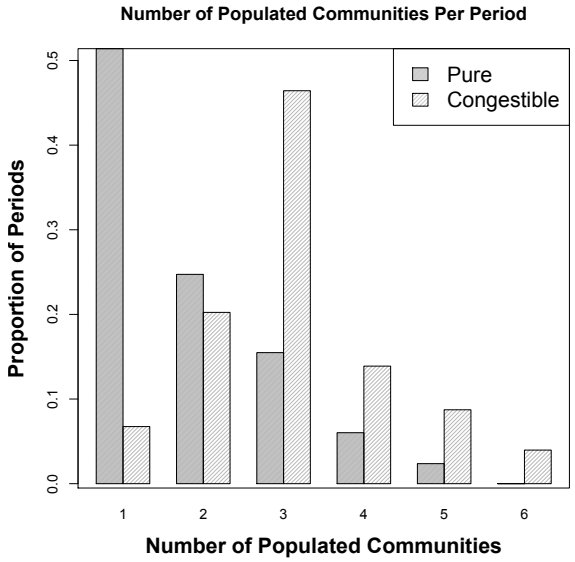

Figure 2: The number of populated communities per period in pure and congestible sessions

At the beginning of each session, subjects typically attempt to create one all-inclusive community, and most participants move into the same location by the fifth or sixth period. In the CPG sessions, contributions decline, this community is soon deserted, and after the fifteenth

period there are typically at least three populated communities in any period. Occasional renewed attempts to establish larger communities also quickly disintegrate. In PPG sessions not characterized by frequent movement, the all-inclusive community endures over most periods, and exit is occasional and temporary.

Community population tends to fluctuate in waves, rather than sudden coordinated movements, and those who move to previously empty locations tend to exit on their own. Whether the subjects' exit is temporary and they will soon rejoin the larger community, or others instead join them in defection, depends on the relative provision levels offered in the old and new communities – though less is needed to entice High Types to follow when the public good is congestible.

In sessions characterized by frequent movement, communities with a population of one are typically joined by others. On the other hand, in sessions in which the entire population is most often together, single member communities are typically not entered by others, and fade from existence when the lone member returns to the large community. This demonstrates that movement into previously empty locations in these non-chasing sessions is most commonly temporary, and again suggests that the PPG sessions characterized by frequent movement are identical to the CPG sessions. Table 3 shows the number of singleton communities, and how often the community is either eventually joined by others or eventually abandoned by the single member.

	Congestion	**Pure; Chasing Sessions**	**Pure; Coexistence Sessions**
% of Populated Communities That Are Singleton Communities	33%	31.5%	13.2%
Persist to Next Period:	67.8%	70%	65%
End with Defection (community disappears):	17.2%	16.67%	61.57%
End With Invasion (community grows):	82.8%	83.33%	38.46%

Table 3: The frequency of singleton communities and whether the singleton community ends with the member exiting (defection) or others joining (invasion)

Result 1.5: Efficiency is 18% above the Nash Equilibrium in the CPG sessions and 21% in the PPG sessions.

While eliminating sensitivity to congestion from the payoff function does increase stability, efficiency increases only slightly.

4.2. Movement and Contribution Patterns are Shaped by the Agents' Preferences for the Public Good

Result 2.1: High Types contribute; Low Types do not

There is a pronounced difference in the behavior of the two types. Though contributing nothing is the dominant myopic strategy for both, High Types contribute much more, consistent

with previous results showing that MPCR affects contributions.[2] Differences in MPCR explain approximately one third of the variation in contributions when the public good is congestible and one fifth of the variation in the pure public good sessions (in which such differences are primarily between-subjects). There are no differences in average contributions between the pure public good and congestible public good sessions.

Result 2.2: Contributions of High Types are sustained, while contributions of Low Types decline.

Contributions of High Types do not significantly decrease over time. However, the contributions of Low Types do decline over the course of the session and, in the congestion sessions, approach zero.[3]

Figure 3 shows the average contribution over time for each type. By the end of the CPG sessions, all but a lone Low Type have learned to never contribute more than five units, while many High Types contribute greater amounts toward the end than they had at the beginning. This may suggest that initial contributions reflect individuals' intrinsic preferences for cooperation (which may be entirely or partially driven by poor comprehension or unfamiliarity with the game form), and that they adjust over time as they learn to be more responsive to their returns and to the free-mobility environment. Approximately half of all High Types in the CPG sessions increase their contributions from the first period to the end of the session while only one Low Type does so.

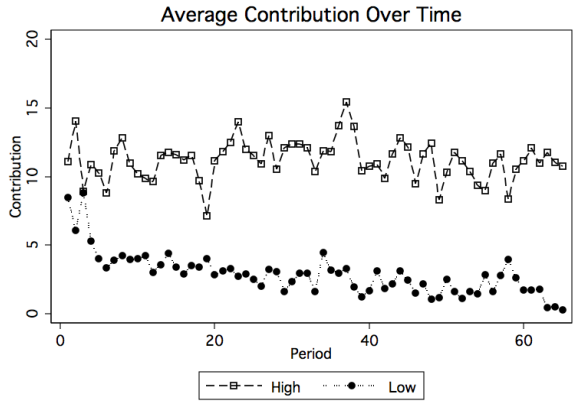

Figure 3a: Congestible Public Good

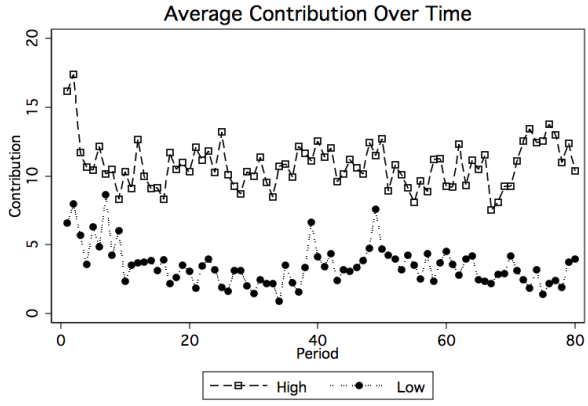

Figure 3b: Pure Public Good

When the public good is pure, the divergence in behavior between types is less stark: some Low Types continue their contributions to the end of the session, while most High Types moderately reduce their contributions. This suggests that subjects are more likely to learn and contribute according to their type during the congestion sessions than those in which the public good is pure. However, if we look only at communities in which all subjects are not together,

[2] The average contribution per period is 10.9 for High Types and 3.2 for Low Types. This difference is significant at less than the .01 level. In addition, differences in contributions between types are not significant when controlling for MPCR.

[3] The decrease in contribution over time is significant for Low Types at $p<.001$ with fixed effects in both the CPG and PPG sessions.

contributions are very similar to the CPG sessions for both types, suggesting that when there is frequent movement, contributions over time do not depend on payoff congestion. There is also evidence of a kind of conditional cooperation: when all subjects are together in stable communities, the behavior of the two types is more similar, with the Highs contributing less and the Lows contributing more.

Result 2.3: High Type contributions decline over community size even in the absence of congestion in their payoff functions.

As predicted, the contributions of High Types decline over community size in the CPG sessions, as MPCR declines as well. However, High Type contributions are also lower in larger communities in the PPG sessions, when MPCR is constant. Thus there is evidence of behavioral congestion, which may contribute to movement from larger communities even when the public good is not congestible: if subjects are aware that large communities experience collective action problems, their movement away from larger communities in the pure public good sessions may also be partially payoff-driven. For Low Types, contributions increase slightly over community size.[4] Figure 4 shows the average contributions of each type over community size.

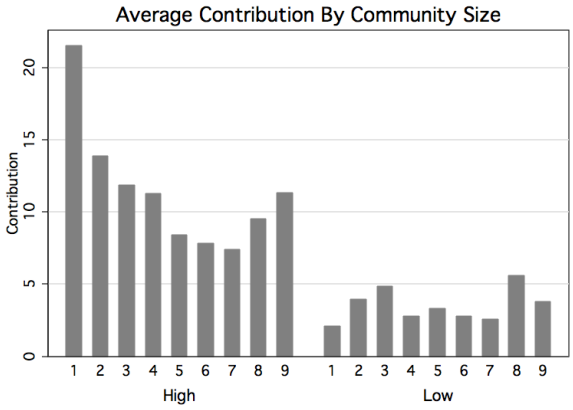

Figure 4a: Congestible Public Good

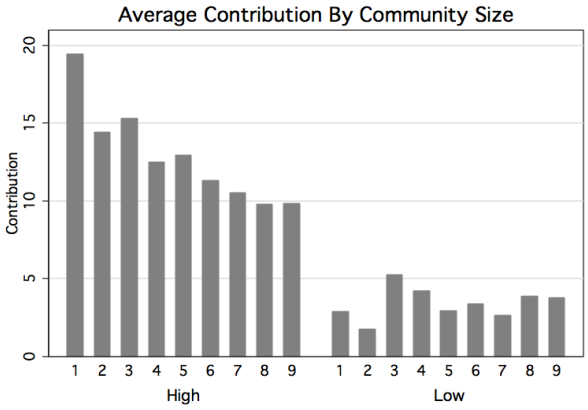

Figure 4b: Pure Public Good

Similarly, if we look at the probability of contributing any non-zero amount over community size, there also is a slight decline in the High Types' likelihood of contributing in both pure and congestible public good sessions, and a slight increase in the Low Types likelihood of contributing.

Result 2.4: High Types move more often than Low Types when the public good is congestible. Movement is less common and High Types do not move significantly more often when the public good is pure.

---

[4] Low Type contributions are weakly positively correlated with community size in both the congestion and pure public good sessions, and both are significant at the .01 level. High Type contributions are negatively correlated with community size in both types of sessions (significant at the .01 level for each), with the magnitude of the effect approximately double in the congestion sessions.

When the public good is congestible, High Types move in 21.2% of all opportunities while Low Types move in 13.4% of opportunities. When the public good is pure, High Types move in 11% of opportunities and Low Types move in 10.4% of opportunities.[5]

Result 2.5: High Types move into smaller communities and are also more likely to found communities by moving into previously empty locations.

A *founder* is an individual who moves into a previously empty location. Forty-two of the fifty-nine founders in the pure public good sessions are High Types and seventy of the seventy-eight founders are High Types in the congestion sessions. High Types are significantly more likely to found communities, even after controlling for their more frequent movement, but this difference is less pronounced when the public good is pure.[6]

4.3. Within-Type Differences

While there is significant difference in the average contributions of the two preference types, there is also considerable variation within types. In particular, there is greater variation in the contributions of the High Types – while most Low Types do not contribute, there are both contributors and free-riders among the High Types. Moreover, when subtypes are classified by contribution level, the differences in contribution among the High Types are strongly associated with differences in movement patterns in the congestible public good sessions.

Result 3.1: In the congestion sessions, the High Types who contribute more also move into smaller communities and repeatedly found new communities.

When the public good is congestible, there is a very strong negative relation between the size of communities that High Types join and their average contributions.[7] Figure 5 presents the average contribution of each subject plotted against the average size of the communities he joined, along with linear fits for each type. There is no such across-subject association between size of communities entered and contributions when the public good is not congestible. However, once again, the PPG sessions with frequent movement are similar to the CPG sessions.

In addition, the Low Types who found communities: 1) contribute more than other Low Types (both in the period that they found[8] and overall[9]) but less than High Type founders[10]; and 2) tend to exit communities of similar size as those communities exited by High Type founders.

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[5] The difference between types in the CPG sessions is significant at p=.01, as is the difference between CPG and PPG sessions.

[6] Between subjects, High Types are significantly more likely to found new communities with p=.03 in CPG and p = .08 in PPG.

[7] Removing contributions to singleton communities – which is a costless signal for High Types – from the average does not alter this result.

[8] 7.29 vs. 3.5

[9] 6.04 vs. 3.5

[10] High Type founders contribute 22 units on average they start a new community, while Low Types contribute 7.29.

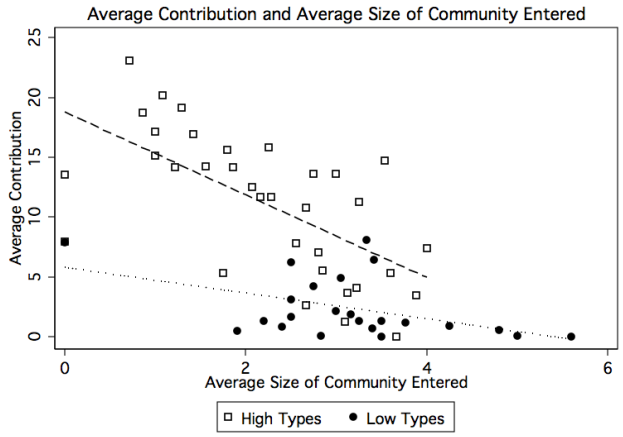

Figure 5: The average personal contribution vs. average size of community joined for each subject in the congestible public good sessions

4.4. Communities Entered vs. Communities Exited

Figure 6 presents the sizes and provision levels of the communities entered and exited, for each preference type and each condition. The darker gray bars show the average population size and total contributions in the community exited (not including themselves or their own contributions) and the lighter gray bars show the average population size and total contributions in the community entered (based on the outcomes in the previous period, which is the information on which they made their movement decision).

High Types tend to exit very large communities in favor of smaller ones, while Low Types exit smaller communities in favor of slightly larger ones.[11]

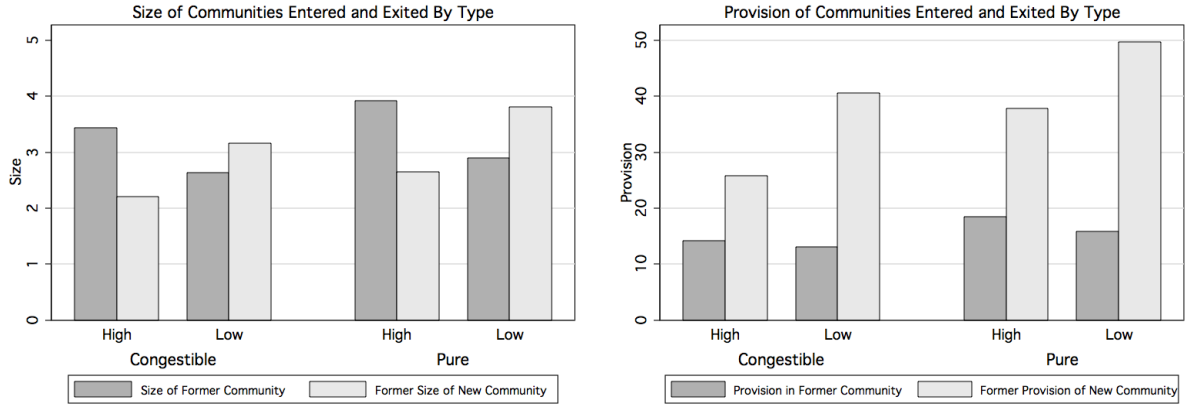

Figure 6: Features of communities entered and exited

[11] This difference is significant at the p =0.01 for High Types and significant for Low Types only in PPG sessions at p=0.05.

Result 4.1: High Types have a much lower threshold for exit than Low Types and, though in similarly sized communities, High Types experience higher provision levels than Low Types.

While both High Types and Low Types tend to exit communities where the others are contributing little in favor of communities with much higher provision levels, the average provision in the community entered is much greater for the Low Types.[12] This suggests that entry fees do deter Low Types from moving into higher performing communities unless these communities offer substantially greater provision and that, despite the frequency of movement, some short-term sorting occurs.

Result 4.2: In the absence of congestion, exit is used as a threat that is typically associated with an increase in contributions.

As discussed in section 4.1, subjects tend to exit the all-inclusive community only temporarily in the PPG sessions. This process of exit and re-entry is associated with a spike in contributions in this community. The average community provision level is 50.4 in the final period before the all-inclusive community breaks up and is 74.8 in the first period in which it has been re-formed.[13]

If a community founder offers a provision level that rivals that in the original community, exit becomes not just a temporary threat that increases cooperation, but instead sets off a cascade of movement to a new location. This, however, can only occur if contributions in the original community have deteriorated dramatically – so that one subject's contribution rivals that of eight – or if a subject founds another community before the others have fully coordinated on a single other location. The significant between-session differences appear to be driven both by the willingness of some subjects to follow a community founder even when the payoffs in their current community are higher and by the willingness of some subjects to continue founding communities before the other communities have stabilized.

4.5. Entry Fees

Locations with differing entry fees can facilitate coordinated congestion avoidance. Since Low Types receive only a 15% return from the public good, myopic best responders should move into a low entry fee community only if the difference in expected contributions between the new community and their current community is greater than 33. However, when the cost of entering is three times as great, the difference in contribution must be greater than 100 units for the Low Types to recoup the entry fee.

Result 5.1: In CPG sessions, high entry fee locations are entered almost exclusively by High Types and both average and total provision levels are much higher there.

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[12] This difference is significant at $p<0.001$.

[13] This difference is significant at $p=0.01$.

High Types account for 85% of the movement into the high entry fee locations. Contributions in these communities are more than double contributions in the low entry fee locations and total provision is also significantly higher. Figure 7 shows the total contributions and average contributions in low entry fee and high entry fee locations. However, these communities are no more stable than the low entry fee communities and neither their population nor provision levels are sustained for any longer. Thus even when the High Types are able to successfully coordinate and separate, provision levels cannot be maintained and the free-riding and chronic relocation problems persist.

Result 5.2: In the PPG sessions, high entry fee locations are entered less frequently. The Low Types are just as likely to enter as are the High Types and, while average contributions are slightly higher in the high entry fee locations, total provision levels are lower.

While subjects are in high entry fee locations approximately 11% of the time in the CPG sessions, they are in these locations only 6.8% of the time when the public good is pure. Though average contributions in PPG sessions are higher in the high entry fee locations, the average population is less than half that in other communities, and so the total provision levels do not rival those in the low entry fee locations.

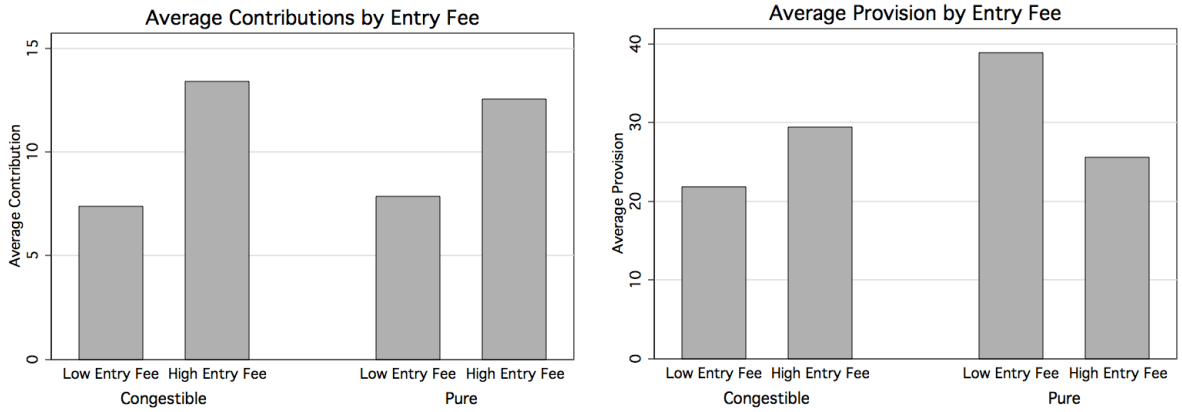

Figure 7: Per-capita contributions and local provision by entry fee

4.6. Agents Move in Response to Public Good Provision

Finally, I analyze the extent to which movement is influenced by local public good provision, for each of the two types of agents.

While the voluntary contribution mechanism differs from the environment considered by Tiebout and the incentives for location choice are very different in this game, movement in response to variation in local provision history does provide support for Tiebout's fundamental premise. In this voluntary contribution environment, Hypothesis 3 says that a partition of agents is stable only if provision is sufficiently similar in all populated locations. The results strongly affirm both of these generalized predictions.

Result 6.1: Subjects are most frequently in the community with the highest provision level and typically move if there is a community with vastly higher public good provision than in their own.

Figure 8 shows the cumulative distribution of how frequently a subject is in a community in which provision levels vary greatly from those in the highest community. The horizontal axis shows the discrepancy between the contributions in the subject's location and those in the location with the highest total contributions.

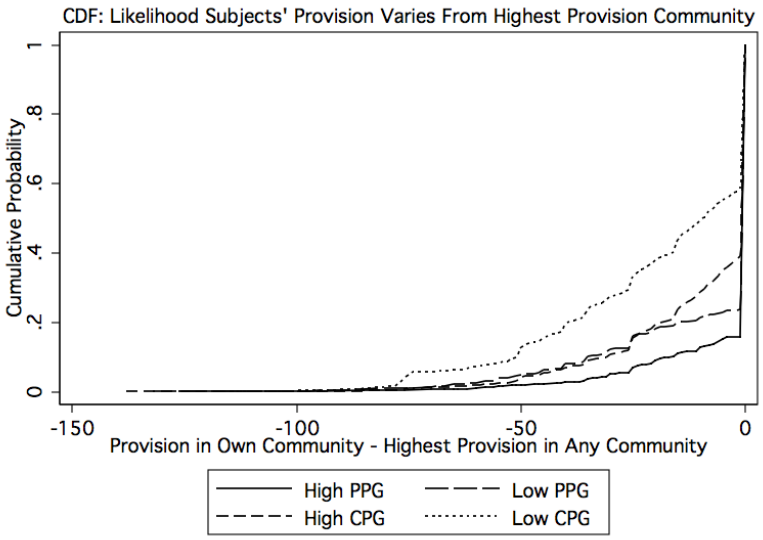

Figure 8: Likelihood that subjects are in a community with inferior provision levels

The likelihood that subjects are in an inferior community depends on the magnitude of the difference in provision levels, with subjects in the community with the highest total provision 53% of the time in the congestion sessions and 80% of the time in the no congestion sessions.

This lends support to the hypothesis that multiple populated communities can persist only if they offer similar provision levels, though this is less true for both High and Low Types when the High Types experience congestion. Probit analysis suggests that the probability of exiting a community is driven by the difference between provision in one's own community and in the community with the highest provision. Additionally, the High Types are both more likely to exit a poorly performing community and more likely to be in the community with the highest provision level than the Low Type subjects, suggesting that the entry fees do generate some sorting.

Result 6.2: Given that agents move, they typically select the community that performed best in the previous period, based on either total or per-capita contribution levels, or the community which would have given them the highest payoff in the previous period.

Figure 9 shows the likelihood that the subjects make the "best" location choice – given that the subject moves – by entering the community with the highest average or total contributions, entering the community in which they would have received the highest payoff had they been in that community making the same contribution in the previous period, or entering a community satisfying at least one of these three criteria. These graphs exclude the movement of

subjects into previously empty locations, as such moves are never myopic best responses and those who frequently take such action exhibit other strategic differences.

The counterfactual tends to best explain which community the subject enters in nearly all of the conditions, though there is considerable overlap.[14] While Low Types are just as likely to choose their new community based on total contributions or average contributions, High Types are more attracted to communities with greater per-capita contributions – even when there is no congestion in their payoffs.[15] Subjects select the previously best performing community with a frequency significantly greater than if they were choosing at random or cycling between the three low entry fee communities.[16] However, neither are they fully myopically best responding to the previous state.

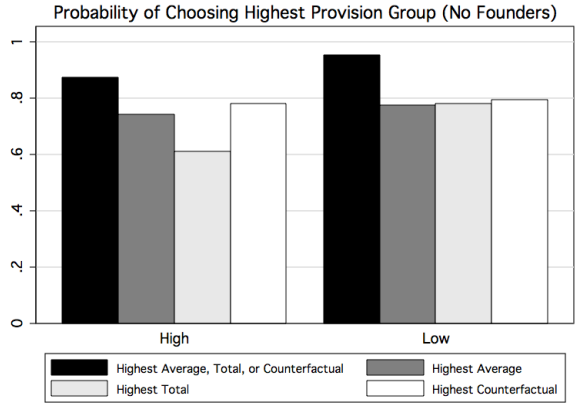

Figure 9a: Congestible Public Good

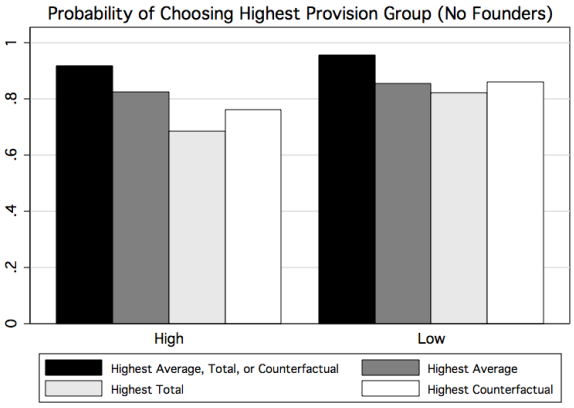

Figure 9b: Pure Public Good

The previous result suggests that subjects who move tend to select the community in which they would have done the best in the previous period, but the question remains whether such movement is, in fact, profitable. Though it is impossible to construct a perfect counterfactual for their continuation payoffs had they not moved, this question may be analyzed through a couple of other approaches.

First, fixed effects regressions show that moves are associated with higher public good returns in the subsequent period, though this difference is not great enough to immediately recoup the entry fees. While the subjects better their location, movement is associated with an average one-period loss of 4 units in the CPG sessions and 2.4 units in the PPG sessions. These results are summarized in Table 4.

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[14] The difference is slight and typically not significant. The one condition that it does not best explain is the movement of High Types when there is no congestion. This suggests that the movement we see in the congestion sessions of High Types exiting larger communities is motivated not only by payoff congestion.

[15] These likelihoods are identical for Low Types in the PPG and CPG conditions. High Types are more likely to enter the community with the highest average contributions than they are to enter the community with the highest total contributions and this difference is significant at the $p<.001$ level in both conditions.

[16] All $p<.001$

Earnings	Congestible	Pure
Move	-3.9*	-2.39*
	(p<.001)	(p=.05)
Community Size	.87*	3.53*
	(p<.001)	(p<.001)
Contribution	1.01*	.92*
	(p<.001)	(p<.001)
Intercept	2.7*	-4.5*
	(p<.001)	(p<.002)
R^2	0.36	0.26
Observations	2853	2745

Table 4: Fixed effects regressions of earnings on movement

Total Payoffs	Congestible	Pure
Moves	45.3*	-58.99*
	(p<.001)	(p<.001)
Contribution	-11.14*	-57.65*
	(p=.358)	(p=.001)
High Dummy	520*	2657*
	(p<.001)	(p<.001)
Intercept	1048*	2887*
	(p<.001)	(p<.001)
R^2	0.49	0.81
Observations	62	53

Table 5: OLS regression of total profits on number of moves

Table 5 shows the effect of movement on the subjects' overall payoffs for the experiment. For both types, frequent movers tend to earn lower payoffs in the pure public good setting. While this effect is not significant for the Low Types, it is large and highly statistically significant for the High Types – in particular, a single additional move is associated with a lower payoff of 88 tokens – over triple their single period endowment and double their typical per-period earnings. Conversely, frequent movement is associated with significantly higher total earnings for both types (significantly so) when the public good is congestible. Additionally, there is only a small, statistically-insignificant earnings advantage for those who "chase" rather than found and develop new communities, controlling for contributions.

4.7. A Note on Subject Pool Differences

While all the subjects in the pure public good sessions were Caltech students, subjects were drawn from three different pools in the congestible public good sessions. The subjects in the first three congestion sessions were Caltech students; in the second two sessions they were Cambridge, MA area residents (including students and non-students); in the final two sessions, participation was restricted to Harvard University students.

Across the CPG sessions, the public good contributions of Caltech students were the most responsive to differences in MPCR, followed by Harvard students, and the population that included non-students was the least responsive.[17] All subjects in the PPG sessions were Caltech students and were no more responsive to differences in MPCR (which were primarily between-subjects) than were the Cambridge populations in the CPG sessions.

Due to the different subject pools and these noted differences in behavior, there is legitimate concern in comparing results from the congestible public good sessions conducted at both Harvard and Caltech to those from the pure public good sessions that were conducted entirely at Caltech, and attributing any differences solely to the rivalry of the public good. To address this concern, the PPG session results are also compared to the three Caltech-only CPG

[17] These differences are all highly significant (p<.01). The Harvard student-only population is closer to the Caltech population if an extreme outlier judged not to be Harvard undergraduate is dropped from the sample. However, the difference is still significant (F=29.6 versus F=57 in Chow Test).

sessions. In *every* result concerning differences between pure public good and congestible public good environments presented in this paper, the differences are even more pronounced when only Caltech subjects are considered.

5 Conclusion

The pattern of those who impose negative externalities perpetually chasing those who impose positive externalities is a fundamental dynamic of community development and group formation.

The poor chasing the rich – or the so-called "musical suburbs" problem – is an oft-considered result in the Tiebout literature, though it is commonly subverted in practice by the implementation of zoning policies, which lead to uniform tax rates (Hamilton, 1975; Wilson, 1998). Throughout U.S. history, the ubiquity of this concern may be seen in the restrictions placed on the mobility of the poor in federal legislation, ranging from the Articles of Confederation, which excluded "paupers" from those who had the right to move freely between states, to the Personal Responsibility and Work Opportunities Reconciliation Act of 1996, which prevented newcomers from receiving welfare benefits beyond what they had been receiving previously for up to a year following their move (Donahue, 1997).

Similarly, trendsetters are forever on the run from both conformists and marketers. Karni and Schmeidler (1990), for instance, show that social consumption preferences can lead to the cyclical nature of fads. This dynamic is borne out in the local neighborhoods of many cities, as artists enter and rejuvenate more affordable areas, only to attract further gentrification and eventually find themselves priced out of their new homes (Ley, 2003).

Finally, the dynamic of chasing has also been observed in social dilemmas games, in which cooperators tend to be the first to exit uncooperative groups or partnerships and will be followed by free-riders and egoists in the absence of strict boundary rules (Ehrhart and Keser, 1999; Ahn, Isaac, and Salmon, 2008/2009).

In this study, I find that this pattern persists in a population of agents with heterogeneous preferences for public good consumption, even when those responsible for the congestion receive little benefit from movement and locating near others, and when there are significant barriers to entry. Further, while sensitivity to congestion does drive a portion of the flight from crowded locations, the dynamic often persists in the absence of payoff congestion. Movement continues even after a strong Nash stable partition has been reached and forward-looking agents have no incentive to coordinate on another location.

This suggests that this chasing dynamic is fundamental and intrinsic, rather than driven purely by congestion or payoff-based incentives. Even when efficiency would have a society pooling its resources into a single community, resentment or unwillingness to be around free-riders suggests that achieving stable groups and communities may be dependent on requiring equal contributions from all members.

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